SHORTER ARTICLES.

PHOTOTROPISM UNDER LIGHT-RAYS OF DIFFERENT WAVE-LENGTHS.

The effect of lateral incidence of light upon *Cormophytes* is of such a nature as to produce a tendency in the plant to arrange its axis parallel to the direction of the incident ray. This response to the stimulus of light is quite general with regard to higher plants, and has long been known under the name *heliotropism*. The term *phototropism*—from its literal meaning more appropriate—has recently been introduced to displace the older term.

The relative phototropic effects of rays of different wave-length have been given by Wiesner * to be greatest between ultra-violet and violet rays, diminishing gradually over to the yellow, where it disappears, then beginning in the orange and reaching a small secondary maximum in the ultra-red. Guilleman's † results resembled those of Wiesner excepting with respect to the yellow. He concluded that curvature takes place under all the rays except the least refrangible heat rays. Sachs himself states that under blue light curvature takes place as in ordinary daylight, and that no curvature whatever takes place behind a ruby-red glass; and he agrees with Wiesner that no curvature takes place behind a yellow screen.

With regard to the decoloring effect upon a fresh alcoholic solution of chlorophyll by rays of different wave-length, the present position is practically that expressed by Vines:‡ 'Sachs and Wiesner have ascertained that the rays of low refrangibility are more active in forwarding it than those of high refrangibility.'

Some investigation of these subjects has been made by the writer, and the results are here given because they differ materially from those referred to, and because it is thought the methods here used to test the matter are less open to objection and more complete than those of the authors mentioned above.

The following named glass plates (each nine by twelve inches) were secured from Bausch and Lomb and are what are commonly called standard 'colors'—*violet, blue, green, yellow, red*—several of each. Window-glass was used to admit daylight, and sheet iron for the opaque screen. These colored plates were examined by the writer with a view to getting the particular spectrum of each, because colored glass can scarcely be represented accurately by simply *naming* the 'color'; for certain colored screens allow other 'colors' to pass than that which would seem from ordinary observation. The curve for each 'color' is plotted approximately in the accompanying

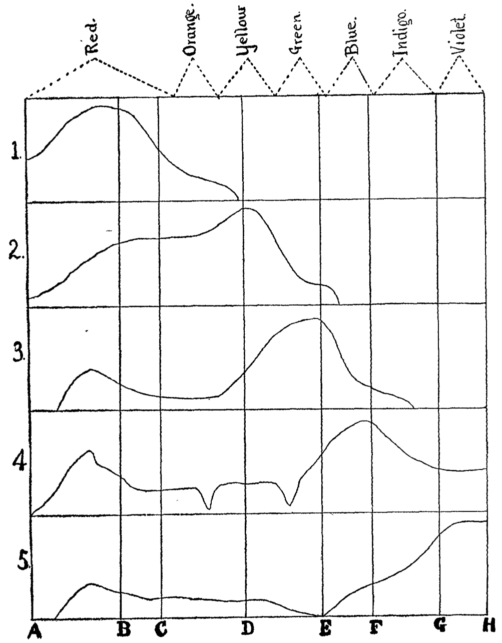

Fig. 1.

figure—1, red; 2, yellow; 3, green; 4, blue; 5, violet. The letters A, B, C, D, E, F, G, H are the ordinary significant points (Fraunhofer lines) of the solar spectrum. It will be seen that there is none of them, with the exception possibly of the red, which can be considered entirely a pure 'color.' However, they are fairly close approximations towards simple 'colors,' and as such are of some significance in regard to the subject under discussion.

In order to test the relative *phototropic*

* 'Die Heliotrop. Erschein. im Pflanzenreich.'

† *Ann. de Sci. Nat.*, IV.; 7; 1858. Both referred to by Sachs, 'Plant Physiol.,' p. 696.

‡ 'Lectures on Plant Physiol.,' p. 266.

effects of the screens mentioned, a number of metal frames were made so as to admit of free insertion of any of the plates into any of the four vertical sides of the frame. The plant to be used in the test was placed within the frame and enclosed on two opposite sides by opaque screens, and on the other two vertical sides were placed plates of two different 'colors.' On the top and the bottom were opaque plates. Then the plant was enclosed within the 'lantern' and placed equally distant from the two color-screens. No light was admitted to the plant excepting that coming through the two screens; and, since the top was covered, the plant was subjected to lateral illumination from two different 'colors' at the same time and from opposite directions. Care was taken to have only diffused daylight enter the screens and to have it equal in intensity. Now it seemed reasonable to conclude that if curvature of the stem of the plant took place toward *one* of the colored screens, the light which penetrated *that* screen produced most phototropic stimulus. The lanterns, not being actually air-tight, permitted the plant to live under more natural conditions of temperature, moisture and air than could be obtained by means of a double bell-jar.

The results obtained are summarized as follows and are represented by the curve given in Fig. 2, *I*. They rank in order named: *blue, white* (window glass), *violet, green, yellow, red, dark* (opaque). Between certain pairs of these screens the difference is not very great, but there is a positive difference in every case.

The main differences between these results and those of Wiesner, Guilleman and Sachs are in regard to the blue, the yellow and the red. Sachs states, p. 696, that curvature takes place behind a blue solution of ammoniacal oxide of copper as in full daylight. This is scarcely exact, because curvature is more prominent behind the blue screen than behind diffused daylight. It is also shown clearly here that curvature *does* take place behind red and behind yellow, though they produce less of a phototropic stimulus than any of the others, the yellow being stronger than the red. Wiesner states that no curvature takes place behind yellow, though he assigns some phototropic effect to red. An extra series was arranged to test the point as to whether no curvature takes place behind yellow or red. Lateral illumination was given through each of these two screens in different lanterns, and it was found that both produced distinct curvature. The lanterns were arranged so as to admit diffused skylight and also, at other times, weak diffused light from the room through the screens. In every case there was the same result.

Another series of experiments was performed with these colored screens to determine the decoloring effect of such light upon chlorophyll in solution. The solutions were

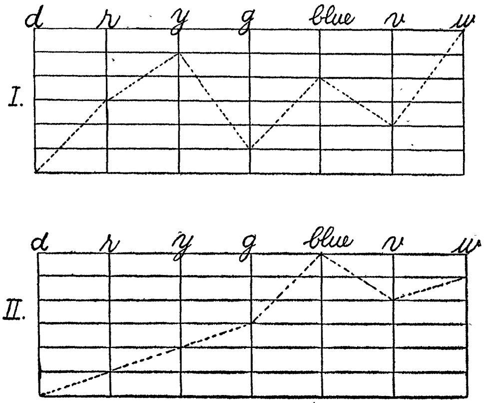

FIG. 2.

fresh alcoholic solutions and in each test the solutions were of exactly the same concentration, but solutions of different degrees of concentration were used to see if strength of solution had anything to do with the results. The conclusions reached were as summarized in Fig. 2, *I*, and in the following order commencing with the quality of light having the greatest decoloring effect: 1, *Diffused light* (in no case was direct sunlight used in the test); 2, *yellow;* 3, *blue;* 4, *red;* 5, *violet;* 6, *green;* 7, *darkness*. The result of this experiment showed that there was but small relationship between the phototropic effects and the decoloring effects upon chlorophyll in solution. It is quite clear that there is little in common (see Fig. 2, *I* and *II*). Sachs and Wiesner both say that the rays of low re-

frangibility produce greater decoloring effect than those of high refrangibility, but from the results obtained here it would seem that decoloration is in no way directly or inversely proportioned to refrangibility. It will be seen that the blue and the red are close together here, while in the solar spectrum they are far apart.

In the accompanying Fig. 2, *I* is given the curve of decoloration of an alcoholic solution of chlorophyll with the screens already described. The vertical lines represent *relative* quantity of effect—*d*, darkness; *r*, red; *y*, yellow; *g*, green; *v*, violet; *w*, weak diffused light. In Fig. 2, *II* is given the curve for relative phototropism. In both cases no attempt is made to represent the actual difference between any two as compared with any other two, *e. g.*, in Fig. 2, *II*, *blue* is three units above *green* simply because it happens to be stronger (in effect) than *diffused light*, which is stronger than *violet*, which is stronger than *green*; nor is it intended that the 'colors' indicated shall be in the exact position of the spectrum, though so far as the 'colors' are concerned they are in that order.

In nearly all the experiments the apparatus was indoors, and the light exposure chiefly north. Some light came from the east and about an equal amount of exposure toward the west. The first experiments were made in the greenhouse, but it was found that too much heat was produced, resulting in the wilting and even in the death of the plants. However, so far as carried on, the results were identical with those under diffused light.

The plants which proved most susceptible to phototropic influences were barley, wheat and tobacco seedlings. The best, most positive and the quickest results were obtained with wheat and with barley seedlings from five to forty mm. high. Other seedlings used were *Catalpa*, *Datura*, bean, pea, corn, sunflower and pumpkin.

No attempt is here made to deduce a physiological or a physical law from these phenomena because it is thought that sufficient data are not yet at hand; nor is there any quantitative effect estimated as existing between any two of the screens used. It is quite clear, however, that the statements of Sachs and others, namely, that the effect, whether phototropic or bleaching of chlorophyll solution, varies as the refrangibility, is not correct. It may be, however, that had the formulæ of their screens been given, it might be possible to see how they arrived at their results.

On looking at the spectra of the screens here given it may be seen that the blue permits considerable of other 'colors' to pass through, especially red. Now, since the phototropic effect of blue is greater than that of diffused daylight, the conclusion naturally follows that some portion of the solar spectrum is negatively phototropic because the blue as well as the other 'colors' passes through window glass. The question at once is suggested then as to where in the spectrum this negative portion is; but seeing that all the 'colors' here given are positively phototropic, the one conclusion is left, and that is but a mere suggestion, namely, that it may occur in those darker bands in the blue represented by the sharp down curve in its spectrum.

It is the intention of the writer to investigate this point by securing screens as nearly as possible corresponding to those portions of the spectrum; and at the same time to examine other intervening 'colors.'

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SCIENTIFIC NOTES AND NEWS.

At the last meeting of the Rumford Committee of the American Academy of Arts and Sciences, the sum of three hundred dollars was granted to Professor W. J. Humphreys, of the University of Virginia, in aid of his research on the shift of spectrum lines due to pressure; and the sum of two hundred and fifty dollars to Professor N. A. Kent, of Wabash College, in aid of his research on the circuit conditions influencing electric spark lines.

Dr. Carlos J. Findlay, of Havana, well known for his work on yellow fever, has been elected president of the American Public Health Association. The next meeting of the association will be held in Havana in April.